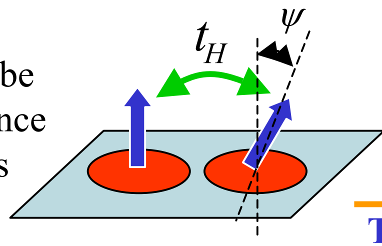
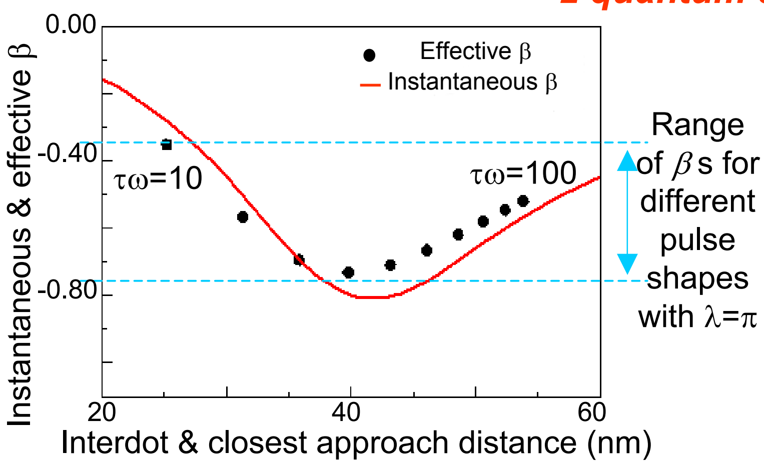
Zeolitic Materials for Nanoscale Electronics & Quantum Computation

In several proposals for solid-state quantum computers, electron spins in quantum dots are used as **qubits**. We have been studying the effect of **spin-orbit coupling**, which leads to a small spin rotation whenever an electron tunnels between dots (for GaAs $\psi \sim 0.1$), on various quantum computation schemes. In the presence of **spin-orbit coupling**, we show that exchange-based quantum gates can be utilized, and controlled by the variance of just two parameters β and λ , thus simplifying the implementation of spin-based quantum computation.

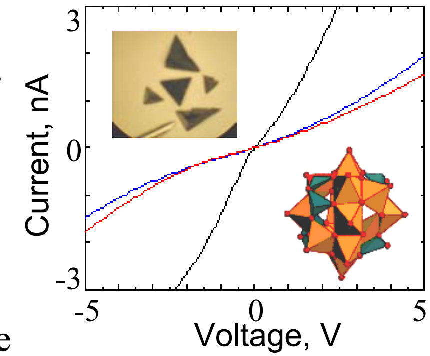


2 quantum dots

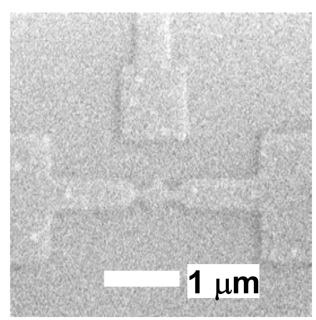


$$U=\exp\text{-}i\lambda\{S_1.S_2 + \beta z . (S_1 x S_2) + \gamma(S_1.S_2 - S_1^z S_2^z)\}$$

A $V_{10}As_{12}O_{40}$ cluster compound synthesized hydrothermally. Upper inset, a photograph of the crystals (a few mm³ in size). Lower inset, the cluster structure, as determined by crystallography. Also shown are electronic current-voltage characteristics of the compound.



The project aims to investigate, both experimentally and theoretically, the feasibility of quantum computation in an array of single-electron transistors (SETs) or quantum dots. The SET arrays are either fabricated by top-down fabrication methods, or chemically synthesized and self-assembled.



An aluminum SET, with its gate in close proximity, fabricated on a GaAs substrate by electron beam lithography. The tunnel barriers are formed by side oxidation of the narrow regions connecting the source and island and drain and island respectively.

Nanoscale Interdisciplinary Research Team, DMR grant 0103034

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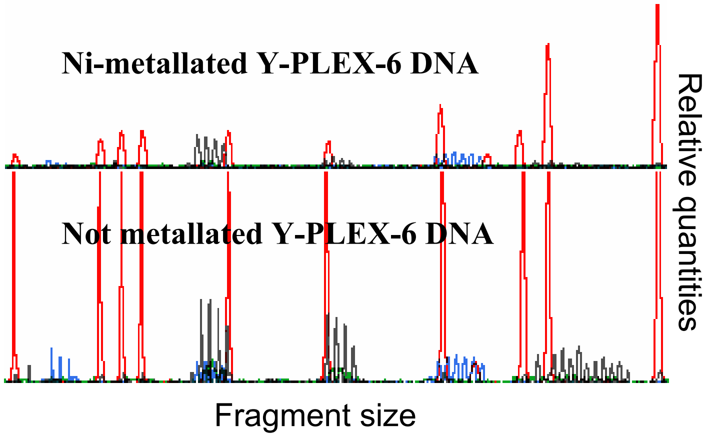
Broader impact



In Forensic Identification: Divalent metal ions such as Zn^{2+}, Co^{2+}, and Ni^{2+} contaminate forensic DNA samples. Here, we demonstrate the influence of Ni+2 on Y-PLEX 6, a recently developed set of Y-chromosomal DNA markers used for the detection of male specific DNA in rape kits. Although there is a marked difference between the metallated and unmetallated samples (the graph above), we have also developed a simple procedure that reverse these negative effects and allows for contaminated DNA samples to still be typed for forensic identification.

Education and outreach

During two months in summer 2004, Prof. Kerwin C. Foster of Dillard University (New Orleans, LA) was a visiting professor at Florida State University, and pursued research with Prof. Bonesteel. Prof. Foster developed a numerical code for modeling double quantum systems, in which many orbitals are kept per dot, (in previous work, only one orbital per dot has been used - a good approximation only in the limit of very small dots.) Using Prof. Foster's code we are now studying the effects of spin-orbit coupling for larger quantum dot systems (50-100 nm), with the goal of determining the feasibility of spin-orbit based quantum computation in such systems.

Andrew McNamara, an undergraduate funded through an NSF REU fellowship for summer 2004, has developed the software and technique to perform oxidation lithography with our atomic force microscope. A wide variety of patterns (lines, ellipses, polygons, even letter fonts) can be imported and written on substrates as oxidized lines. Subsequent removal of the oxide results in a trench, defining the nanoelectronic devices. The picture shows the versatility of the method, as expressed by Andrew. The oxidized patterns were obtained on the semiconductor GaAs at -20 V cantilever voltage, 40% relative humidity, and 1 µm/s writing speed.